The impact of temporal changes on retrievals of *Karenia brevis* harmful algal blooms in the West Florida Shelf.

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Objective

To develop an effective *KB* HAB detection and tracking approach for use with **VIIRS** satellite which unlike **MODIS** has no 678 nm fluorescence channel.

So that HAB monitoring capabilities can be extended to **VIIRS** and continue to support local authorities in their forecasting of beach conditions, including health warnings etc.

- In the US, it is estimated over $100 million is lost annually as a result of Harmful Algal Blooms (HABs). The West Florida Shelf (WFS) is frequently plagued by *Karenia brevis* (*KB*) HABs which kill fish and posing a health hazard to humans. This frequently results in beach warnings and closings and adversely impacting the tourist economy.
- *Karenia brevis* HABs in the WFS have been successfully detected, quantified and tracked from **MODISA** using the normalized fluorescence height (nFLH) and Red Band Difference (RBD) techniques which rely on measurements from the 678 nm fluorescence channel on **MODISA**. Unfortunately, **VIIRS**, the successor satellite to **MODISA**, does not have a 678 nm fluorescence channel.

Approach applied in WFS for *KB*-HABs Retrievals

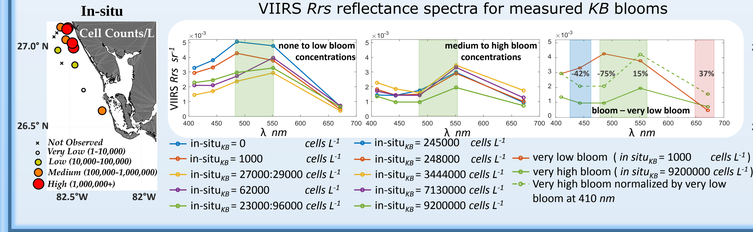
- **First** we relate VIIRS Rrs (486,551,671) to $a_{ph}443$ using NN for estimation of concentrations $a_{ph}443$ which is approximately proportional to [Chl*a*].
- **Then**, in a second critical step, we evolve limiting criteria which make use of two facts (*Cannizzaro, 2009*).

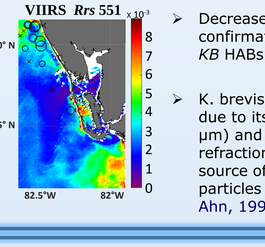
I. Low backscatter bb_p551 **≤ *max specific*** (Equiv. $Rrs_{551} \leq 0.006\ sr^{-1}$)

II. High phytoplankton a_{ph443} **≥ *min specific value.*** (Equiv. [Chl*a*] ≥ 1.27 *μg L⁻¹*)

*These limiting criteria (**F1** & **F2**) are applied to filter retrieved VIIRS retrievals of a_{ph443} & Rrs_{551} with residual images effectively delineating and quantifying KB HABs.*

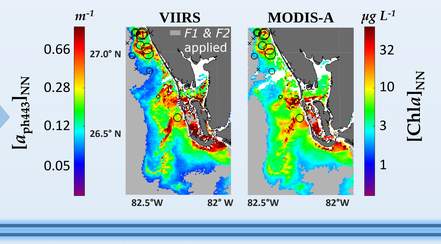
Results from one day bloom (10/09/2012): *KB* in-situ measurements vs. VIIRS & MODIS NN retrievals





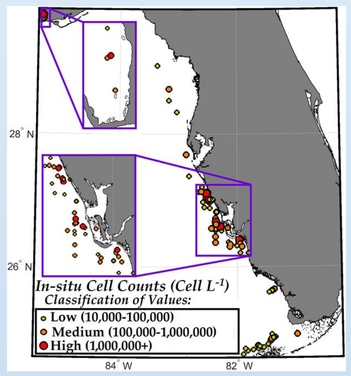
- Decrease in green reflectance provides confirmation that we are dealing with *KB* HABs of increasing intensity
- K. brevis is an ineffective backscatterer due to its large particle size (20–40 μm) and relatively low index of refraction (1.05). Instead, the primary source of bb_pr in oceanic waters is particles less than 1 μm (Morel and Ahn, 1991; Stramski and Kiefer, 1991).

KB blooms



Results from the VIIRS mission (2012-2016): *KB* in-situ measurements vs. VIIRS NN and 4 other retrieval algorithms

Showing *in situ* locations of *KB*

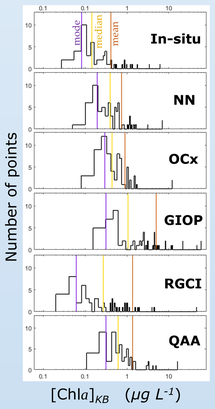


Regression and Delta Statistics

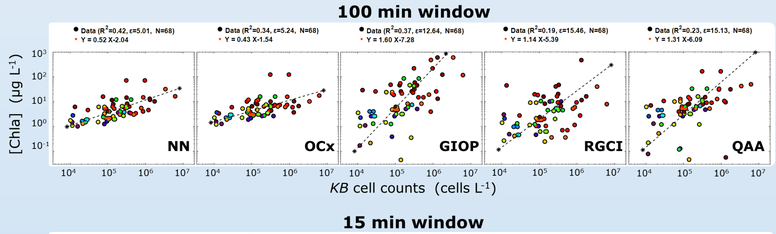
KB in-situ & retrievals algorithms		[*Chla*] data values (*μg·L⁻¹*) mean	media n	mod e	ST D	min	ma x	N
In-situ		4.1	1.4	0.8	9	0.1	62	68
NN	VIIRS 100 minutes window	7.4	3.9	1.9	12	0.99	71	68
OCx		9	4.4	2.9	20	1.19	122	68
GIOP		50	10.6	3.1	118	0.04	597	68
RGCI		13.7	2.7	0.6	56	0.24	461	68
QAA$_{v5}$		13.7	6.2	3.2	28	0.05	163	68

y-axis [*Chla*] (*μg·L⁻¹*)	*x-axis* *KB* Cell Counts (*cells L⁻¹*)		R^2	ε	Slope & Intercept	N
NN	VIIRS 100 minutes window		0.42	5.01	$y = 0.52x - 2.04$	68
OCx			0.34	5.24	$y = 0.43x - 1.54$	68
GIOP			0.37	12.64	$y = 1.60x - 7.28$	68
RGCI			0.19	15.46	$y = 1.14x - 5.39$	68
QAA			0.23	15.13	$y = 1.31x - 6.09$	68
NN	VIIRS 15 minutes window		0.79	0.42	$y = 0.47x - 1.83$	18
OCx			0.55	0.72	$y = 0.34x - 1.13$	18
GIOP			0.45	3.57	$y = 1.20x - 5.25$	18
RGCI			0.50	2.28	$y = 0.75x - 3.55$	18
QAA$_{v5}$			0.34	3.82	$y = 0.90x - 3.88$	18

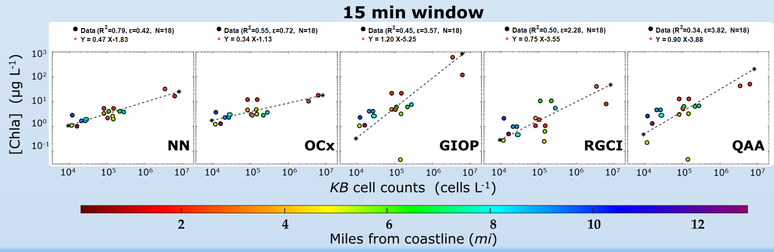
distributions



100 min window

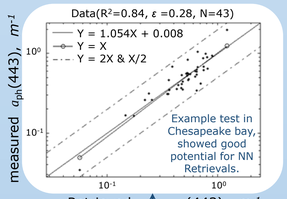


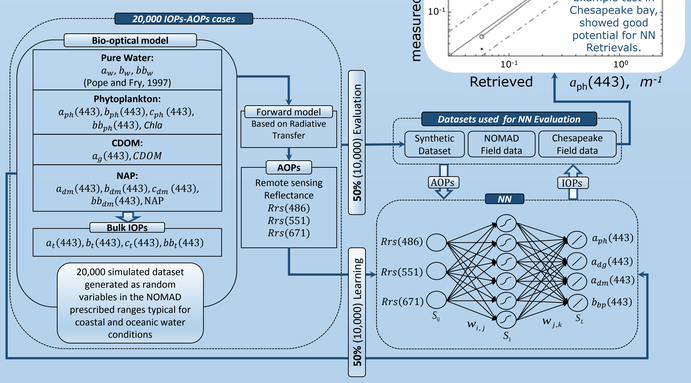
15 min window



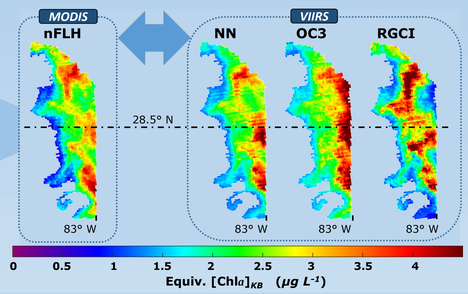
Neural Networks (NN) Algorithm Architecture

- NN is being developed and trained on (10,000) simulated dataset based on wide range of coastal and oceanic NOMAD IOPs.
- Tested and validated on another 10,000 simulated dataset and field measurements.
- Uses VIIRS Rrs input at 486, 551 & 671 nm, values used at a longer λ which are not greatly impacted by atmospheric correction.
- Output of (a_{ph}, a_{dg}, a_{dm} & bb_p) all at 443 (which at the peak of a_{ph} and thus exhibit most variation) Where a_g and a_d are mutually constrained through an empirically derived relationship based on a study of NOMAD values.



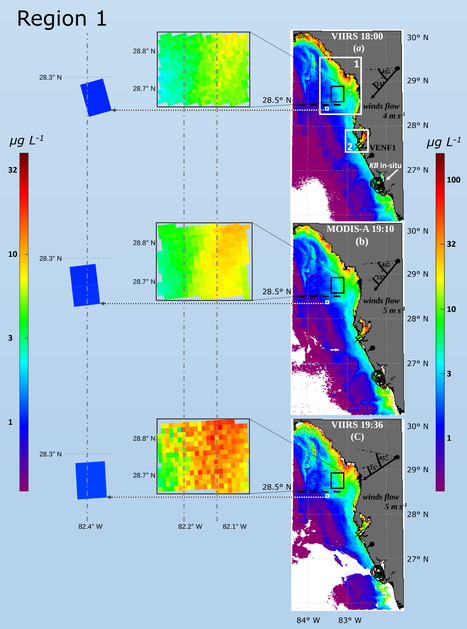


Example of MODIS nFLH vs. VIIRS NN & other algorithms

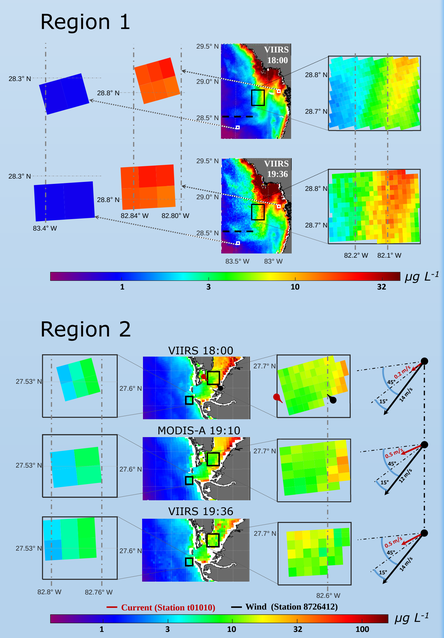


Diurnal variability on 11/03/2014

OC3 [Chl*a*]



NN [Chl*a*]



Region 1 bloom, as delineated by the [*Chla*] color contour in the images, appears, qualitatively, to increase in concentration and expand in the southwest direction over the 96 minute interval between the consecutive overlapping VIIRS-MODIS-VIIRS images.

Region 2 shows VIIRS and MODIS-A sequential retrievals from Tampa Bay, where a bloom seems to shrink in [*Chla*] densities opposite to the wind and current direction, implying that there are a complexity of factors at work, possibly including downwelling.

Results of field measurements showing temporal variability on 1/19/2017

Station	Depth (m⁻¹)	Lat. (°)	Long. (°)	Start Time (GMT)	End Time (GMT)	K. brevis (cells L⁻¹)	Time diff (minutes)
CV1701	0.7	27.31836	-82.59587	17:20	17:25	7,280,000	120
CV1713	0.7	27.31713	-82.59606	19:21	19:25	1,552,000	
CV1702	0.7	27.31500	-82.59831	17:48	17:52	1,776,000	87
CV1712	0.7	27.31480	-82.59846	19:15	19:19	1,326,000	
CV1703	0.7	27.31467	-82.60061	18:00	18:04	1,024,000	68
CV1711	0.7	27.31408	-82.60059	19:09	19:12	1,110,000	
CV1704	0.7	27.31296	-82.60277	18:07	18:12	964,000	54
CV1710	0.7	27.31289	-82.60298	19:03	19:06	590,000	
CV1705	0.7	27.31077	-82.60677	18:18	18:22	642,000	37
CV1709	0.7	27.31085	-82.60664	18:55	18:59	576,000	
CV1706	0.7	27.30681	-82.61356	18:27	18:32	952,000	21
CV1708	0.7	27.30686	-82.61364	18:48	18:51	690,000	

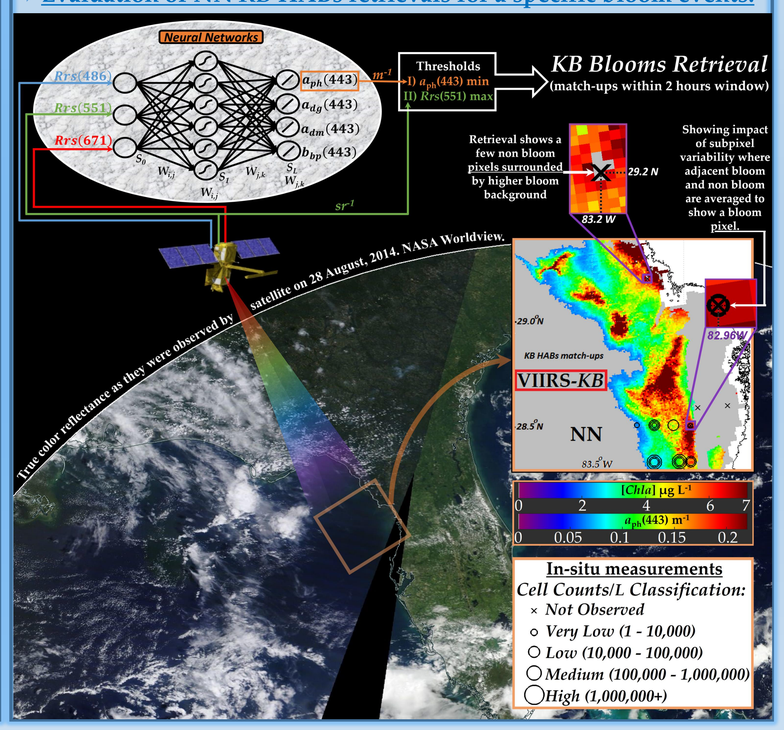
Figure shows transect of outward and return legs of field measurements.

These results illustrate both the intra pixel variations that can typically occur (as well as inter pixel variations) and also confirm the temporal variations that can be expected. The relative contributions of drift or upwelling/downwelling to the results are not known.

Conclusions

- Comparison results show that VIIRS [Chl*a*] data are significantly improved for all algorithms with limited time windows, even over coastal regions with quite large [Chl*a*] values.
- The use of NN retrievals of $a_{ph}443$ from VIIRS show promise as a viable algorithm for the Florida coastal region, where CDOM and/or shallow waters are dominant.
- Retrieval show importance of temporal considerations.
- Further detailed comparisons with in-situ measurements are planned and considerations of subpixel variability addressed.

Evaluation of NN *KB* HABs retrievals for a specific bloom events.



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